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REVIEW ARTICLE

A practical approach to paediatric emergencies in the radiology department

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Abstract Acute life-threatening events involving children in the radiology department are rare. Nonetheless, radiologists should be competent in the relatively simple procedures required to maintain or restore vital functions in paediatric patients, particularly if their practice involves seriously ill or sedated children. This article gives a practical overview of the immediate management of paediatric emergencies that the radiologist is likely to encounter, using a structured (ABCD) approach. Emphasis is given to the early recognition of respiratory embarrassment and shock, and early intervention to prevent deterioration towards circulatory arrest. The management of cardiorespiratory arrest, anaphylaxis and convulsions in children is also addressed.

Keywords Emergencies · Resuscitation · Anaphylaxis · Convulsions · Radiology · Children

Introduction

Acute life-threatening events requiring rapid intervention in hospitalized children are relatively rare and only a small percentage of these are likely to occur in the radiology department or involve the radiologist [1]. Nonetheless, the need for immediate action in such circumstances requires that the radiologist has an adequate working knowledge of the principles of paediatric resuscitation and of the interventions required to prevent further deterioration of a severely ill child.

This article gives an overview of the principles of the recognition and management of the acutely ill child with an emphasis on those problems that are most likely to present in the radiology department under circumstances where the radiologist is the only doctor present. These include respiratory insufficiency and shock developing in a child who was already ill or as a result of sedation, cardiorespiratory arrest, anaphylaxis and convulsions. Specifically excluded are children undergoing cardiac catheterization who are usually under the direct care of a paediatric cardiologist and anaesthesiologist.

Particular attention is paid to the early recognition of respiratory failure and shock and to the immediate treatment of emergency situations in which the radiologist may be required to intervene before further help arrives.

Pathophysiology of cardiorespiratory arrest in children

Cardiac arrest in children is seldom a primary event, but is usually preceded by a period of respiratory or cardiovascular insufficiency leading to hypoxaemia and shock [2]. During this phase considerable organ damage, in particular to the kidneys, liver, gut and brain, can occur before the circulation fails completely (Fig. 1). The prognosis for children following a cardiac arrest is extremely poor, but the prodromal phase is usually detectable clinically, so the emphasis of paediatric emergency medicine is on the early recognition of and intervention in respiratory impairment and shock [3].

A specific pathological diagnosis of the cause of impairment of the child's vital functions is less important to effective intervention than a global physiological appreciation of the mechanisms involved. To simplify and

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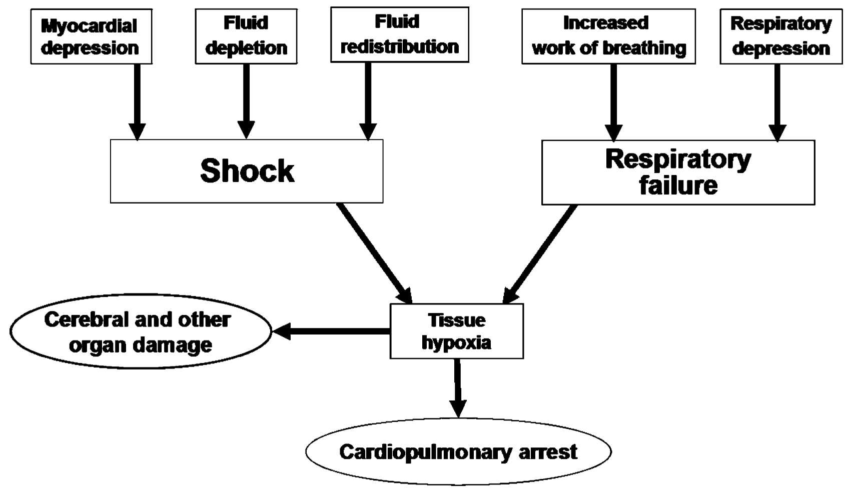


Fig. 1 Common mechanisms of cardiopulmonary arrest in children, adapted from [3]

accelerate decision-making in an emergency, the ABCD (Airway, Breathing, Circulation, Disability) approach is widely adopted for both diagnosis and management. In contrast to adults, the majority of acute life-threatening events in children have a respiratory cause [2]. Use of the ABCD approach prioritizes the actions to be taken in a medical emergency in a logical order such that the flow of adequately oxygenated blood to the vital organs is maintained or restored.

Recognition of the severely ill child

Recognition of deranged vital functions is essential to effective intervention. Using the ABCD approach incorporated into a rapid clinical examination it is possible to assess the condition of the child in less than a minute to confirm or refute a suspicion of respiratory insufficiency or shock (Table 1).

Rapid assessment of the airway and breathing

During the clinical examination the upper airway and breathing are effectively assessed simultaneously, but it is essential to differentiate between the two. Effective breathing requires both an open airway and effective ventilation. The upper airway may require manoeuvres or equipment to maintain or improve patency and the ventilation may require assistance. To attempt to ventilate a child without first optimizing airway patency is incorrect.

Assessment of the airway and breathing focuses on three factors: the work of breathing, the effectiveness of breathing, and the effect of increased work of breathing or respiratory insufficiency on other organs. Clinical signs of increased *work of breathing* will often give the first clue to a developing problem. The respiratory rate increases as a response to hypoxia or respiratory acidosis. As the normal respiratory rate, and other vital signs, vary with age, it is necessary to measure these accurately and compare them to the expected values for the child (Table 2). In some situations, such as an overdose of opiates and other sedatives, neurological disease or raised intracranial pressure, a *decrease* in respiratory rate may be the first sign of developing respiratory insufficiency. Also, as a child with increased work of breathing fatigues, the respiratory rate will decrease precipitously towards apnoea. In some conditions, particularly raised intracranial pressure, the respiratory rate may be normal but the respiratory pattern is irregular.

Intercostal, subcostal and (particularly in infants) sternal retraction is seen when the work of breathing is increased. This can occur in health as the oxygen requirement and carbon dioxide production increase during exertion, but occurs at rest when lung compliance is decreased or airway resistance is increased. Retraction is a particularly useful sign in young children who have a more compliant chest wall making retraction more prominent. Accessory respiratory muscles are also activated when work of breathing increases. Although relatively inefficient in young children, accessory muscle use does lead to useful vital signs, notably the “head-bobbing” of infants when attempts to raise the thorax using the neck muscles pulls the head downwards with each breath.

As normal ventilation is almost silent, added sounds should alert the radiologist to a cause or consequence of increased work of breathing. These can include stridor and wheezing due to upper and small airway obstruction, respectively. The intensity of these sounds is related to the amount of air that passes over the obstruction. Thus, as the child fatigues and less air is displaced, stridor and wheeze may become *less* prominent and this should not be assumed to be a sign of improvement. Grunting is commonly heard

Table 1 Rapid clinical examination of the seriously ill child, according to the ABCD system, adapted from [13, 42].

Upper airway		Open, Partially or fully obstructed
Breathing	Work of breathing	Respiratory frequency Retraction Added sounds Accessory muscles Flaring of the nostrils
	Effectiveness of breathing	Chest expansion Air entry Pulse oximetry
	Effects of respiratory insufficiency	Heart rate Skin colour Level of consciousness
Circulation	Cardiovascular signs	Heart frequency Pulse volume Capillary refill Blood pressure Enlarged liver
	Effects of shock	Respiratory frequency Skin colour and temperature Level of consciousness
Disability (neurological condition)	Neurological signs	Level of Consciousness (AVPU) **A**lert, responding to **V**oice, responding to **P**ain, **U**nresponsive Pupil reactions Muscle tone, abnormal movements and posture
	Effects of neurological conditions on other organs	Respiratory rate and pattern Heart rate Blood pressure

in small children with noncompliant lungs who attempt to increase their end-expiratory pressure by partially closing the glottis.

Flaring of the nostrils can also be an early sign of impending respiratory impairment particularly in infants.

Assessment of the *effectiveness of breathing* is essentially the evaluation of the passage of air into and out of the lungs. Respiratory excursions are part of this assessment, but are not on their own sufficient evidence of ventilation as excursions continue for some time even in the presence of a totally obstructed airway. Listening and feeling for the warmth of expired air with a hand or cheek above the

Table 2 Normal vital signs in children according to age [3].

Age (years)	Respiratory rate (/min)	Heart rate (/min)	Systolic blood pressure (mmHg)
<1	30–40	110–160	70–90
1–2	25–35	100–150	80–95
2–5	25–30	95–140	80–100
5–12	20–25	80–120	90–110
>12	15–20	60–100	100–120

child's mouth and nose is a more reliable method of detecting the presence or absence of ventilation (the so-called look-listen-feel method; Fig. 2).

Bilateral auscultation of the thorax in the axilla, together with assessment of the degree and symmetry of chest expansion, is the acid-test of ventilation and gives a global impression of the displacement of air. The effectiveness of oxygenation can be quantified using a pulse oximeter, which is an extremely useful monitor for all sick children or those undergoing procedures under sedation. However, the concomitant use of oxygen, which is virtually always indicated in the child with potential respiratory failure, makes hypoxia a late and very serious sign.

The increased work of breathing leads to *effects on nonrespiratory organs*. Hypoxia or hypercarbia gives rise to a number of nonspecific but useful signs of respiratory impairment, such as tachycardia. Hypoxia has a direct depressant effect on the heart rate which in the early stages of respiratory failure is overshadowed by the neural and hormonal stress response. Bradycardia therefore occurs very late in respiratory failure and is often a preterminal sign. Cyanosis is frequently an unreliable sign of hypoxia as a child's apparent skin colour is influenced by many factors including genetics, vasoconstriction due to stress, haemoglobin defects and the ambient lighting. The pulse oximeter is more useful, although it may be difficult to use

Fig. 2 Assessing the airway and breathing of a child [41]

when tissue perfusion is reduced in shock and the reliability of the reading is affected by haemoglobin abnormalities [4]. As respiratory insufficiency increases, the child's mental state will show a progression from agitation to apathy and coma, which will parallel the effectiveness of ventilation.

Rapid assessment of the circulation

The rapid assessment of the circulation is primarily aimed at the early detection of shock by evaluation of both circulatory parameters and the effect of inadequate tissue perfusion on other organs.

Among the *circulatory parameters,* tachycardia is an early but non-specific sign of potential shock. An infant's cardiac output is more dependent on the heart rate than that of an older child or adult as the stroke volume is less adaptable. Bradycardia, which occurs late in shock, is therefore a very serious sign.

The pulse volume gives a global impression of the state of the circulation, but this can be difficult to assess in children of different ages. The child's response to shock usually involves vasoconstriction, which initially can be very effective at maintaining blood pressure and may be so severe that peripheral pulses are difficult to feel or absent. Measurement of the blood pressure is part of the rapid assessment of the circulation, but a normal blood pressure does not exclude shock. On the other hand, hypotension is a sign of advanced shock requiring immediate intervention. The expected systolic blood pressure (SBP, in mmHg) for the child's age (in years) can be estimated from the formula: SBP = 80 + (age × 2).

The capillary refill time is measured by pressing on the sternum with a finger for 5 seconds to blanche the skin and counting the time until the skin colour returns, which normally occurs within 2 seconds [5]. Capillary refill time can also be prolonged in early septic and anaphylactic shock where erythema might suggest increased skin perfusion. Capillary refill time is affected by both ambient and body temperature, which limits the value of peripheral assessment [6]. One further limitation of great importance in the radiology department is the dependency of the test on ambient lighting [7]. The predictive value of capillary refill has been questioned and the test may be more specific than sensitive, but it is quick and easy to perform and remains widely used [8].

Vasoconstriction will lead to peripheral cooling and it is sometimes possible to assess improvement or deterioration in the child's condition by the progression of the line of warm-cold demarcation on the limbs. An enlarged liver should alert the examiner to cardiogenic shock or cardiac failure.

Physiological compensation mechanisms for potential shock lead to *effects on other organs* that are readily detected clinically. These include tachypnoea, generally without other signs of increased work of breathing, mental changes from agitation to coma, and oliguria, which is less useful in the emergency situation.

Rapid assessment of the neurological condition

As mentioned above, the child's neurological condition can be strongly influenced by respiratory or circulatory insufficiency and the rapid neurological assessment should be interpreted in this light. For simplicity in an emergency, the child's global mental state can be categorized into four levels using the AVPU system: Alert, responding only to Voice, responding only to Pain, and Unresponsive. A painful stimulus can be applied to a child who does not respond to vocal stimulation by sternal or nail-bed pressure or pulling on the hair. A child who only responds to pain is likely to have a Glasgow coma score of 8 or less.

As well as the mental state, the muscle tone, pupil response and presence of abnormal movements or posture give useful information concerning the child's neurological condition. Respiratory and cardiovascular signs, such as irregular breathing, bradycardia and hypertension, are generally late and serious signs of acute neurological conditions.

Using the system described above it is possible to assess a child's condition within 1 minute and to decide on the necessary intervention. The same system should be used to regularly reassess the child's response to therapy.

Early intervention in respiratory failure and shock

Using a few simple interventions it is possible to prevent further deterioration in the vital functions of a child with incipient respiratory or circulatory failure until help arrives. A detailed discussion of specific therapy of the underlying conditions is outside the scope of this article, which therefore focuses on the general principles involved (Fig. 3). For the calculation of drug and fluid doses the weight of a child under 10 years of age can be estimated using the formula 8 + (age × 2), although this formula may need to be adjusted for different populations [3, 9, 10].

The essence of the initial management of all acute life-threatening disorders in children, including neurological conditions, is to improve the provision of oxygenated blood to the tissues and this can be approached logically using the ABC system. Therefore, severely ill children should be given a high concentration of oxygen, for which there are few contraindications, although the lowest oxygen concentration necessary to maintain an adequate oxygen saturation should be used in premature neonates, those with duct-dependent congenital heart disease and in heart failure with a large left-to-right shunt.

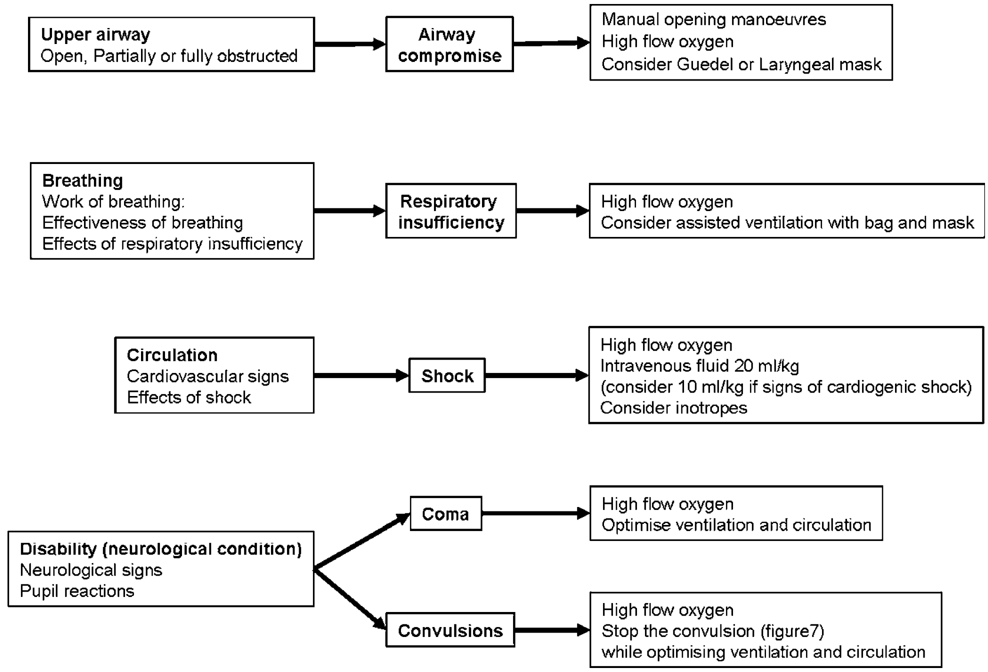


Fig. 3 General approach to the initial management of acute life-threatening events in children

The first step is to open the upper airway using an appropriate manual manoeuvre such as the jaw-thrust, in which the lower jaw is lifted anteriorly with the fingers behind the mandibular angle. This lifts the tongue from the posterior pharyngeal wall. With a little practice the jaw thrust can be maintained with one hand leaving the other free for manual ventilation if needed. A simple device such as a Guedel airway may be helpful in maintaining airway patency and, for those with the necessary experience, a laryngeal mask is often superior. However, neither device will be tolerated by the child with intact pharyngeal reflexes in whom their use may precipitate vomiting and aspiration [11]. Opening the airway and delivering supplementary oxygen may be all that is required in some circumstances such as airway obstruction due to sedative overdose.

If the child is breathing inadequately despite a patent upper airway, artificial ventilation should be started using a suitable system and 100% oxygen. A self-inflating bag is probably the easiest system for the infrequent user, but care should be taken to ensure that this is properly assembled by testing its functionality before use. Such devices need to be attached to an oxygen reservoir if a high oxygen concentration is to be achieved. The adequacy of artificial ventilation is assessed by visual inspection of thoracic expansion and the response of the vital signs. An increase in oxygen saturation is a reassuring sign of improving oxygenation, but gives little information as to the adequacy of ventilation, for which end-tidal carbon dioxide measurement is more reliable.

Supplementary oxygen is also indicated in impending or established shock, which also requires intravascular fluids, inotropes and vasoactive agents in varying proportions according to the type of shock. Hypovolaemic shock, which may occur in dehydration from, for instance, abdominal emergencies, or following trauma, requires replacement fluid in aliquots of 20 ml/kg followed by reassessment of the circulation. Septic shock may require very large quantities of fluid replacement, inotropes and vasoconstrictors. Cardiogenic shock generally requires inotropic support, often in combination with agents to reduce the afterload, such as phosphodiesterase inhibitors, and may respond to a single dose of 10 ml/kg of intravenous fluid, but excessive fluid administration should be avoided. The management of anaphylactic shock is discussed below.

The treatment of all types of shock requires vascular access in the form of a peripheral venous cannula, a central venous catheter or an intraosseous device through which drugs and fluids are administered via the bone marrow cavity. Insertion of an intraosseous device can be easily learned and is safe and may even be faster to site than an intravenous cannula [12]. All drugs and intravenous fluids likely to be needed in an emergency can be administered intraosseously and blood concentrations are known to be similar to those following central venous infusion, provided the drugs are properly flushed [13, 14]. A drill for the insertion of an intraosseous device has recently been introduced and shows much promise as an even faster and more effective method of gaining vascular access in children [15].

Guidelines for paediatric cardiopulmonary resuscitation

Although the essence of the management of paediatric emergencies is the early recognition and treatment of potential respiratory failure and shock to prevent cardiopulmonary arrest, radiologists should also be aware of the current resuscitation guidelines for children, which are shown in Fig. 4. The relative infrequency and inhomogeneous nature of paediatric resuscitation means that good evidence of effect from clinical studies is hard to come by and many aspects of the guidelines have been decided by extrapolation from adult studies. For ease of teaching and retention the guidelines have been kept as simple as possible. As a consequence, guidelines for basic and advanced life support of children differ little from those for adults.

As respiratory causes are the most common causes of cardiopulmonary arrest, paediatric life support begins with opening of the airway and administration of five ventilations (rescue breaths) preferably with 100% oxygen. In the absence of sings of life, such as movement, coughing or reasonable attempts to breathe (but not agonal gasping), cardiac massage should be started by compressing the lower third of the sternum to one third of the thoracic depth at a rate of 100 compressions per minute. The best way to achieve this depends upon the child's age. The most effective technique in infants is the method attributed to Thaler in which the thorax is encircled with both hands while the sternum is compressed with the thumbs one finger-breath above the xiphoid process (Fig. 5) [16]. In older children the lower third of the sternum is compressed with one or two hands according to the size of the child and of the rescuer. If the child is *not* intubated, compressions

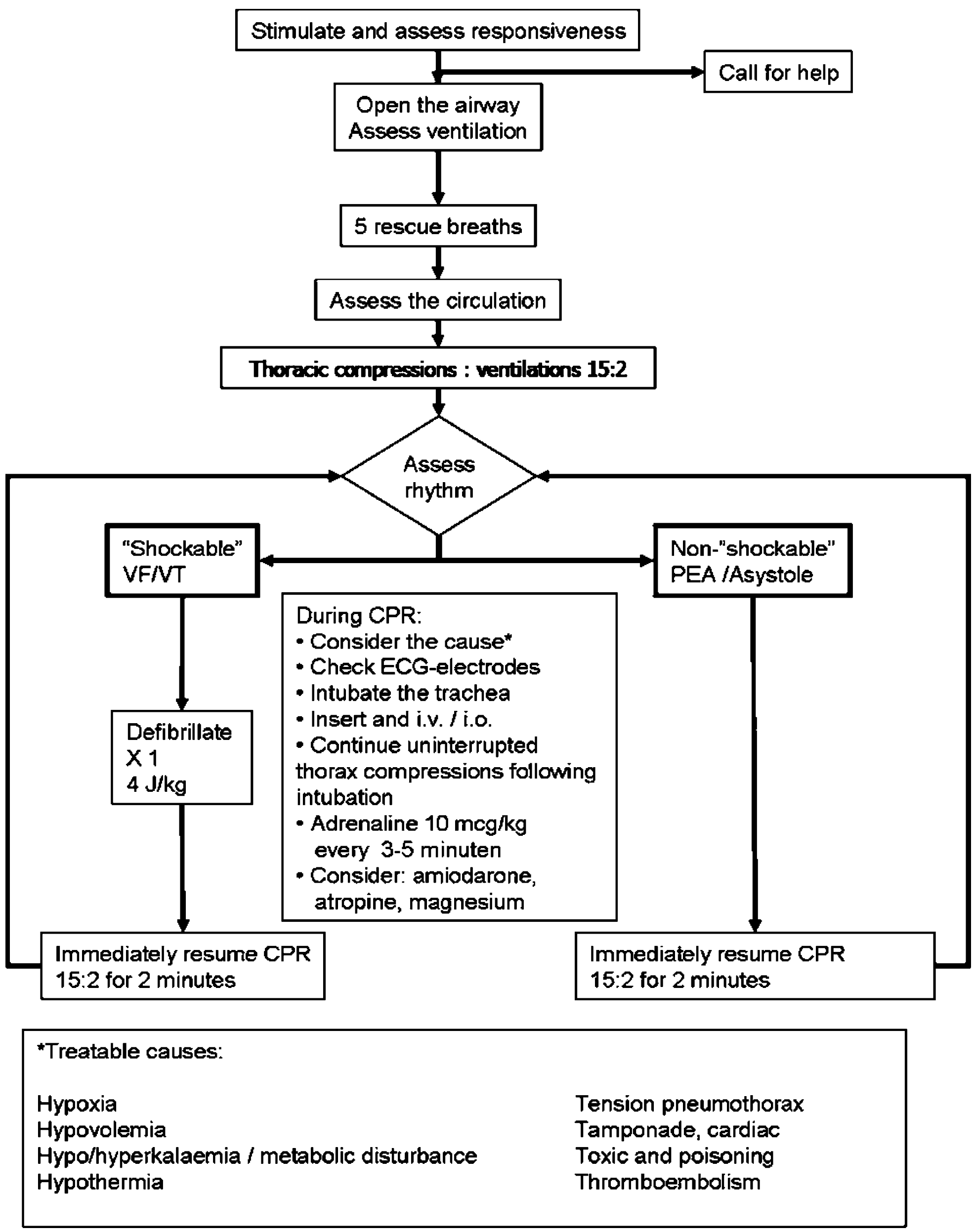
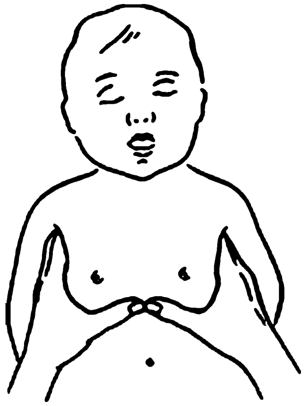


Fig. 4 Universal algorithm for paediatric life support [13]

Fig. 5 Chest compressions in an infant [3]



are briefly interrupted every 15 compressions to allow for two ventilations. However, higher ratios of compressions to ventilations may produce better coronary flow and the adult ratio of 30:2 is also advocated as an option for lone rescuers [13, 17]. Continuous thorax compressions are used in intubated children.

Paediatric advanced life support is aimed at maintaining adequate blood flow to vital organs while the cause is detected and treated. Cardiac arrhythmias are a less frequent cause of circulatory arrest than in adults. Nonetheless, it is important to exclude ventricular fibrillation by ECG monitoring as soon as possible, as the effectiveness of defibrillation decreases rapidly with time [18]. The recommended energy of manual defibrillation in children is 4 J/kg regardless of the type of defibrillator used. Children older than 8 years can be safely defibrillated according to the adult recommendations (150 J biphasic). Automatic external defibrillators can be safely used in children older than 1 year, and probably also in infants [19, 20].

The ECG of most children with a circulatory arrest will show either asystole or pulseless electrical activity that may take many forms from normal sinus rhythm to a wide complex “dying heart” rhythm. In both cases, it is important to maintain the artificial circulation with good oxygenation and thorax compressions and vasoconstriction with adrenaline 10 µg/kg every 3–5 min. Higher doses of adrenaline are no longer considered helpful [21]. At the same time the cause of the arrest should be actively sought. A widely used mnemonic for the potential causes of circulatory arrest is the “four H’s and four T’s” (Fig. 4), which can be applied to both children and adults, although the relative frequency of the underlying mechanism varies with age. In children, hypoxia is relatively more frequent and thromboembolism rare. Tension pneumothorax and cardiac tamponade, which may complicate invasive procedures, show similar clinical signs in adults and children and confirmation of the diagnosis radiographically or by echocardiography should present no problem in the radiology department. Treatment is by percutaneous drainage. In the case of a tension pneumothorax, immediate percutaneous thoracocentesis in the midclavicular line of the second intercostal space with a large intravenous cannula should be performed, followed by insertion of a thorax drain. Tension pneumoperitoneum, which may complicate reduction of intussusception, presents with severe respiratory embarrassment, and is also treated by immediate percutaneous drainage followed by surgical exploration [22].

As soon as the appropriate equipment and expertise is available, a child with a circulatory arrest should be intubated to guarantee the airway and allow optimal ventilation. Early intubation by inexperienced personnel has been show to not benefit the patient, and may be detrimental [23]. Therefore, bag-and-mask ventilation should be continued initially. Following intubation, thoracic compressions should be continuous at a rate of 100/minute. The recommended initial ventilation rate is 12–20/min depending on the age of the child, but may need to be adjusted according to blood gas analysis.

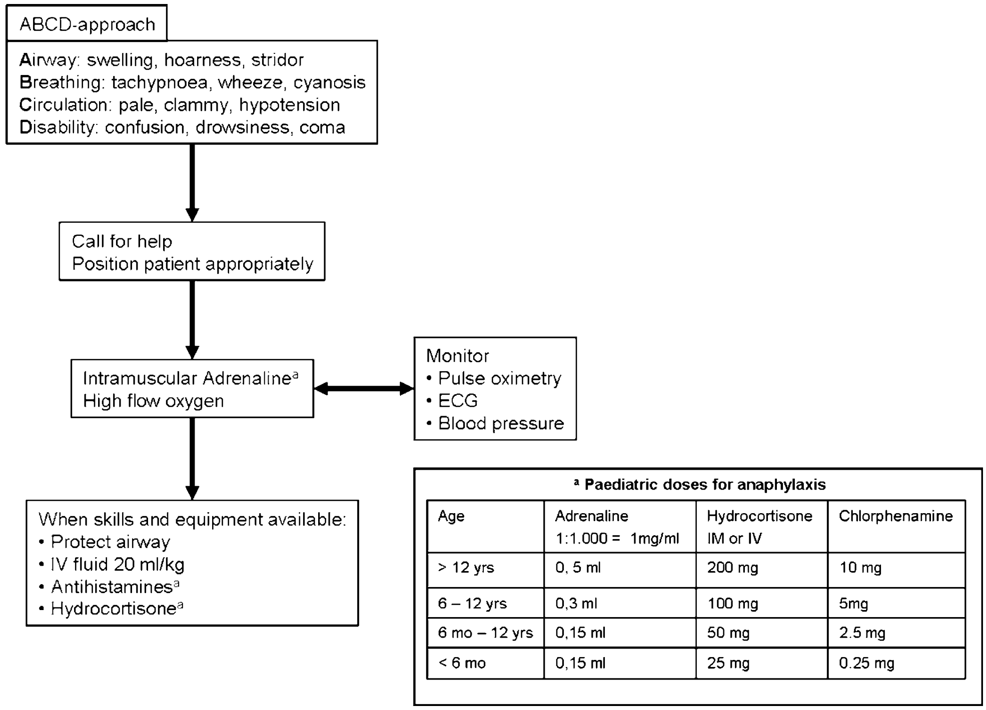
Serious dysrhythmias in children are rare, but occur more commonly than complete circulatory arrest, and may present as otherwise unexplained shock particularly in unmonitored infants. Supraventricular tachycardia is the most frequent and usually responds to a rapid intravenous bolus of adenosine 100 µ/kg, or to a second dose of 200 µg/kg. Failure to respond may be an indication for synchronous cardioversion with 1–2 J/kg, preferably under anaesthesia. Ventricular tachycardia may be secondary to electrolyte disorders or intoxication and is treated initially with an intravenous infusion of amiodarone 5 mg/kg, or by cardioversion as for supraventricular tachycardia. Vagal bradycardia is often transitory, but may require intravenous atropine 20 µg/kg (minimum dose 100 µg).

Emergency treatment of anaphylaxis in children

Life-threatening anaphylactic reactions are an uncommon but ever-present potential complication of the administration of contrast medium [24]. Severe anaphylaxis presents with the sudden onset of upper airway and respiratory symptoms (stridor, wheeze, respiratory embarrassment), shock (initially due to vasodilatation and fluid sequestration) and skin and/or mucosal changes. Circulatory arrest may follow. The onset may be delayed by 5–10 min following intravenous injection of the antigen [25]. If treated promptly and correctly, the prognosis is good; however, overtreatment of minor reactions and vasovagal episodes with adrenaline is believed to be associated with significant morbidity [26, 27]. A skin reaction on its own does not constitute an anaphylactic reaction.

If conscious, the child should be allowed to adopt the most comfortable position. Raising the legs may improve

Fig. 6 Emergency management of anaphylaxis in children in the radiology department, adapted from [28]



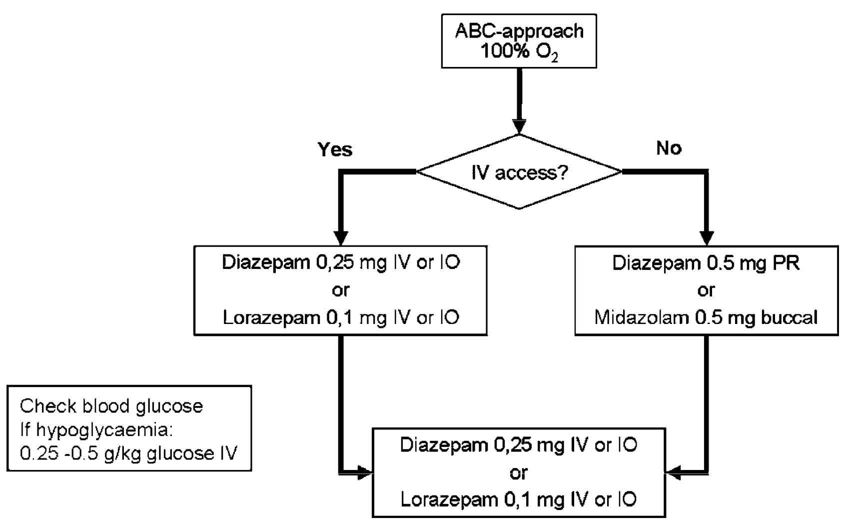
[a] **Paediatric doses for anaphylaxis**

Age	Adrenaline 1:1.000 = 1mg/ml	Hydrocortisone IM or IV	Chlorphenamine
> 12 yrs	0, 5 ml	200 mg	10 mg
6 – 12 yrs	0,3 ml	100 mg	5mg
6 mo – 12 yrs	0,15 ml	50 mg	2.5 mg
< 6 mo	0,15 ml	25 mg	0.25 mg

venous return, cardiac output and blood pressure in shock, but sitting upright may improve breathing if airway obstruction or wheeze is predominant. Immediate treatment of a severe reaction consists of high-flow oxygen, *intra-muscular* adrenaline, vascular access and fluid in aliquots of 20 ml/kg. Intravenous adrenaline should only be given by those experienced in its use or if circulatory arrest occurs. The intramuscular dose of adrenaline is 10 µg/kg, repeated at intervals of 5 min according to the response, but recent British guidelines recommend a simplified dosage schema as shown in Fig. 6 [28]. Adrenaline helps to maintain the circulation by vasoconstriction and a positive inotropic effect, and is a bronchodilator. It may also help reduce the release of histamine and other mediators [29]. Large quantities of fluids may be needed. Patients should be monitored with ECG, pulse oximetry and noninvasive blood pressure monitoring. Antihistamines and steroids have a secondary role, but the latter may be useful if bronchospasm is prominent, in which case bronchodilator therapy, such as salbutamol, should also be given [30].

Cardiac arrest in the context of anaphylaxis is treated along standard lines as described above. Following the reaction all patients should be investigated to confirm the diagnosis and trigger agent [28].

Fig. 7 Emergency management of convulsions in children, adapted from [42]



Emergency treatment of convulsions

Convulsions may occur during radiological examinations due to fever, head injury or other causes. Convulsions increase the cerebral oxygen requirement and that of other organs while reducing the effectiveness of ventilation. Cerebral hypoxia occurs when compensation mechanisms fail and the immediate goal of therapy is to stop the convulsion as soon as possible whilst maintaining cerebral oxygenation [31].

Immediate treatment (Fig. 7) consists of maintaining a patent upper airway, high-flow oxygen, and an anticonvulsant of which the benzodiazepines are the most commonly used. If the child has no vascular access, rectal diazepam 0.5 mg/kg or buccal midazolam 0.5 mg/kg may be given. The intravenous route should be used if available. The intravenous dose of diazepam is 0.25 mg/kg, but lorazepam 0.1 mg/kg may be equally effective and cause less respiratory depression. Blood glucose should be measured as hypoglycaemia is a potentially serious and easily treatable cause of convulsions particularly in small children [32]. Hypoglycaemia can be reversed with intravenous glucose 0.25–0.5 g/kg (equivalent to 2.5–5 ml 10% glucose per kilogram).

Equipment and training

Guidelines have been produced for the drugs, equipment and monitoring that should be available in the radiology department for use in emergencies and during procedures under sedation [33, 34]. This equipment should be appropriate to the age of the patients attending the department and should be checked regularly. All staff should be aware of its location and the local system of activating the resuscitation team for children.

The general level of knowledge of the treatment of emergency situations among radiologists is believed to be amenable to improvement and the need for further training has been expressed [35, 36]. There is ample evidence that structured resuscitation training of health-care professionals can lead to an improvement in knowledge and skills, but retention times are short especially when these skills are rarely used [37–39]. Retraining at intervals and mock emergency exercises can improve retention [40]. Radiology departments should consider their local educational needs in respect of paediatric emergencies and take steps to rectify these.

Conclusion

The immediate treatment of paediatric emergencies that are likely to be encountered in the radiology department can be structurally approached using the ABCD system. Radiologists should possess the basic competencies involved in maintaining or restoring vital functions, particularly if their practice involves seriously ill or sedated children. Emergencies are very rare, which may lead to a false sense of security. Adequate monitoring and alertness and adequate practice are required for an optimal response. Local protocols, wall charts and individualized resuscitation dose schemes for the sickest children may improve performance when the doctor's cognitive functions are impaired by stress.

Acknowledgements The ABC approach to the assessment of the severely ill child was adapted from the Advanced Paediatric Life Support course of the Advanced Life Support Group (UK) [3], to which the author is very grateful, although a similar approach is widely adopted elsewhere. The resuscitation guidelines are those of the European Resuscitation Council, and are in the public domain. Figures 2 and 5 are reproduced with the permission of the copyright holders.

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References

1. Nadkarni VM, Larkin GL, Peberdy MA et al (2006) First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA 295:50–57
2. Richman PB, Nashed AH (1999) The etiology of cardiac arrest in children and young adults: special considerations for ED management. Am J Emerg Med 17:264–270
3. Advanced Life Support Group (2005) Advanced paediatric life support: the practical approach, 4th edn. Blackwell, Oxford
4. McMorrow RC, Mythen MG (2006) Pulse oximetry. Curr Opin Crit Care 12:269–271
5. Schriger DL, Baraff L (1988) Defining normal capillary refill: variation with age, sex, and temperature. Ann Emerg Med 17:932–935
6. Anderson B, Kelly AM, Kerr D et al (2008) Impact of patient and environmental factors on capillary refill time in adults. Am J Emerg Med 26:62–65
7. Brown LH, Prasad NH, Whitley TW (1994) Adverse lighting condition effects on the assessment of capillary refill. Am J Emerg Med 12:46–47
8. Leonard PA, Beattie TF (1994) Is measurement of capillary refill time useful as part of the initial assessment of children? Eur J Emerg Med 11:158–163
9. Turner NM, Draaisma JM (2003) Een herziene formule voor het schatten van het gewicht van een Nederlands kind. Ned Tijdschr Anesthesiol 16:13
10. Black K, Barnett P, Wolfe R et al (2002) Are methods used to estimate weight in children accurate? Emerg Med (Fremantle) 14:160–165
11. Youngquist S, Gausche-Hill M, Burbulys D (2007) Alternative airway devices for use in children requiring prehospital airway

management: update and case discussion. Pediatr Emerg Care 23:250–258
12. Glaeser PW, Losek JD, Nelson DB et al (1988) Pediatric intraosseous infusions: impact on vascular access time. Am J Emerg Med 6:330–332
13. Biarent D, Bingham R, Richmond S et al (2005) European Resuscitation Council guidelines for resuscitation 2005. Section 6. Paediatric life support. Resuscitation 67[Suppl 1]:S97–S133
14. Buck ML, Wiggins BS, Sesler JM (2007) Intraosseous drug administration in children and adults during cardiopulmonary resuscitation. Ann Pharmacother 41:1679–1686
15. Horton MA, Beamer C (2008) Powered intraosseous insertion provides safe and effective vascular access for pediatric emergency patients. Pediatr Emerg Care 24:347–350
16. Dorfsman ML, Menegazzi JJ, Wadas RJ et al (2000) Two-thumb vs two-finger chest compression in an infant model of prolonged cardiopulmonary resuscitation. Acad Emerg Med 7:1077–1082
17. Turner I, Turner S (2004) Optimum cardiopulmonary resuscitation for basic and advanced life support: a simulation study. Resuscitation 62:209–217
18. Weisfeldt ML, Becker LB (2002) Resuscitation after cardiac arrest: a 3-phase time-sensitive model. JAMA 288:3035–3038
19. Atkins DL, Jorgenson DB (2005) Attenuated pediatric electrode pads for automated external defibrillator use in children. Resuscitation 66:31–37
20. Bar-Cohen Y, Walsh EP, Love BA et al (2005) First appropriate use of automated external defibrillator in an infant. Resuscitation 67:135–137
21. Perondi MB, Reis AG, Paiva EF et al (2004) A comparison of high-dose and standard-dose epinephrine in children with cardiac arrest. N Engl J Med 350:1722–1730
22. Daneman A, Alton DJ, Ein S et al (1995) Perforation during attempted intussusception reduction in children – a comparison of perforation with barium and air. Pediatr Radiol 25:81–88
23. Gausche M, Lewis RJ, Stratton SJ et al (2000) Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. JAMA 283:783–790
24. Katayama H, Yamaguchi K, Kozuka T et al (1990) Adverse reactions to ionic and nonionic contrast media. A report from the Japanese Committee on the Safety of Contrast Media. Radiology 175:621–628
25. Pumphrey RS (2000) Lessons for management of anaphylaxis from a study of fatal reactions. Clin Exp Allergy 30:1144–1150
26. Yocum MW, Butterfield JH, Klein JS et al (1999) Epidemiology of anaphylaxis in Olmsted County: a population-based study. J Allergy Clin Immunol 104:452–456
27. Johnston SL, Unsworth J, Gompels MM (2003) Adrenaline given outside the context of life threatening allergic reactions. BMJ 326:589–590
28. Soar J, Pumphrey R, Cant A et al (2008) Emergency treatment of anaphylactic reactions – guidelines for healthcare providers. Resuscitation 77:157–169
29. Chong LK, Morice AH, Yeo WW et al (1995) Functional desensitization of beta agonist responses in human lung mast cells. Am J Respir Cell Mol Biol 13:540–546
30. Smith M, Iqbal S, Elliott TM et al (2003) Corticosteroids for hospitalised children with acute asthma. Cochrane Database of Systematic Reviews, Issue 1. Art. no.: CD002886. doi:10.1002/14651858.CD002886
31. Lothman E (1990) The biochemical basis and pathophysiology of status epilepticus. Neurology 40:13–23
32. Auer RN, Siesjo BK (1988) Biological differences between ischemia, hypoglycemia, and epilepsy. Ann Neurol 24:699–707
33. The Royal College of Radiologists (2003) Safe sedation, analgesia and anaesthesia within the radiology department. Royal College of Radiologists, London
34. American College of Radiology (2005) Practice guideline for pediatric sedation/analgesia. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/pediatric/pediatric_sedation.aspx. Accessed 30th August 2008
35. Sadler DJ, Parrish F, Coulthard A (1994) Intravenous contrast media reactions: how do radiologists react? Clin Radiol 49:879–882
36. Schellhammer F (2003) Do radiologists want/need training in cardiopulmonary resuscitation? Results of an internet questionnaire. Acta Radiol 44:56–58
37. Kaye W, Rallis SF, Mancini ME et al (1991) The problem of poor retention of cardiopulmonary resuscitation skills may lie with the instructor, not the learner or the curriculum. Resuscitation 21:67–87
38. Nelson MS (1988) How quickly they forget. Am J Emerg Med 6:538–539
39. Ali J, Howard M, Williams JI (2003) Do factors other than trauma volume affect attrition of ATLS-acquired skills? J Trauma 54:835–841
40. Jabbour M, Osmond MH, Klassen TP (1996) Life support courses: are they effective? Ann Emerg Med 28:690–698
41. Vries de W, Turner NM (2006) Lesboek kinderreanimatie: basale reanimatie bij babys en kinderen. Dutch Resuscitation Council, The Hague
42. Turner NM, Vught van AJ (eds) (2006) Advanced paediatric life support: de Nederlandse editie, 2nd edn. Elsevier Gezondheidszorg, Maarsen, The Netherlands